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University of Kentucky

**Observations and Experiments on the Control of
True Tobacco Mosaic.**

BULLETIN NO. 280



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Observations and Experiments on the Control of True Tobacco Mosaic.

By W. D. VALLEAU and E. M. JOHNSON

Because of the large acreage planted to tobacco each year in Kentucky and in other tobacco growing regions, much low-grade tobacco is produced each year, which, in many instances, brings returns that make the growing of the crop questionable from an economic standpoint. In spite of this situation high-grade tobacco continues to bring excellent returns. Growers realize the importance of producing higher quality tobacco but the means by which quality can be improved are not always evident to them. The proper selection of soil has long been recognized as an important consideration, but due to the development of black root-rot, crops have often been a failure on land which previously produced an excellent crop. The selection of strains of tobacco resistant to black root-rot has made possible the production of high-grade tobacco on the diseased soils where the commonly grown varieties would have failed. Thus tobacco growers have come to realize more fully the importance of disease control in the production of high-grade tobacco.

The present bulletin discusses another important disease of tobacco which is so common that many tobacco growers hardly consider it a disease but think of it as an abnormal growth condition of the plant not within their control. It is hoped that a discussion of the nature of the disease, the methods of overwintering and the means by which tobacco plants become infected, will aid tobacco growers in a more intelligent understanding of this heretofore very puzzling condition and will assist in its elimination as a factor in reducing yield and quality of tobacco.

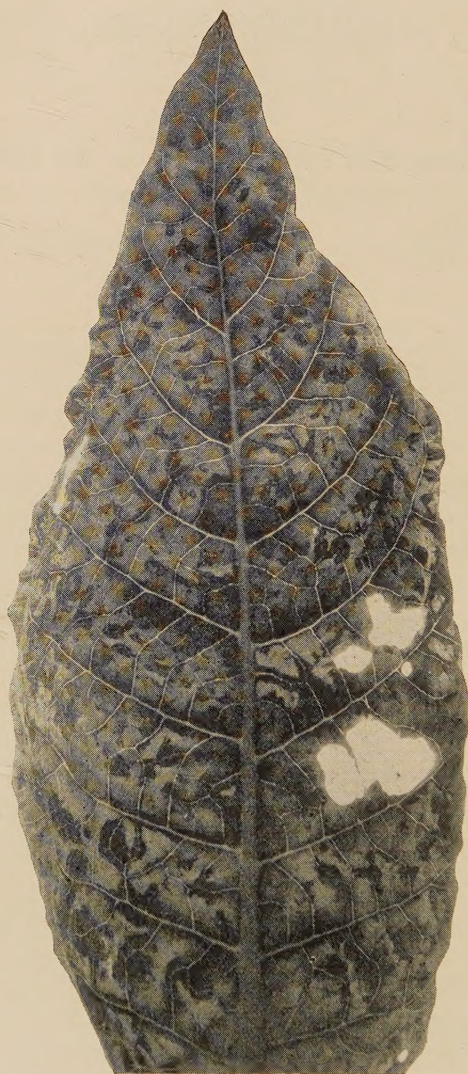


Figure 1.—A leaf from the growing point of a Burley tobacco plant affected with mosaic, showing the mottling which is characteristic of the disease. This is probably a mild form of the disease, the severe form usually causing, besides mottling, also blistering and distortion of the leaf.

NAMES

In the scientific literature the name given to the disease to be discussed is mosaic, so named because of its similarity to mosaic patterns made by inlaying variously colored glass, stone or other material. Tobacco growers have given various names to it. In the Burley section it is commonly known as "french" or "dry weather french" in contrast to the true frenching of tobacco, which is often called "wet weather french." In western Kentucky it is similarly known, but it is also commonly called "walloon." As the term mosaic is so descriptive of the disease and as there is another disease of tobacco commonly known as frenching, it seems preferable to adopt the name mosaic for this particular disease.

DESCRIPTION

The mosaic disease is so common that it hardly needs description. The new leaves, whether in the top or in the suckers, are mottled, as shown in figure 1. The dark areas usually consist of nearly healthy tissue while the lighter areas may be various shades of green or sometimes yellowish. There appears to be more than one strain of the disease. In a more severe type than that pictured in figure 1 the dark areas, instead of being smooth, are often raised into quite large blisters, giving the leaf a very distorted shape. In the mild type the plant makes nearly normal growth, the older leaves gradually losing their mottled appearance and becoming nearly an even green color, while in the severe type the plants are much stunted (figure 3) and the older leaves, altho more uniform in color than the younger ones, remain distorted and stunted and often develop small dead spots which may spread and unite, leaving large burned areas on the leaf (Fig. 2). This is sometimes spoken of as rust, but is distinct from the bacterial leaf-spots, wildfire and angular leaf-spot, which are commonly called rusts.

CAUSE OF THE DISEASE

The mosaic disease is caused by an ultra-microscopic organism; that is, a living organism too small to be seen with the high-



Figure 2.—An old leaf from a Burley tobacco plant affected with a severe form of mosaic. The frilled appearance and the numerous dead spots are usually characteristic of the severe type of mosaic.



Figure 3.—Effect of inoculation with two strains of tobacco mosaic at setting time on the growth of Burley tobacco. Rows A and B inoculated with severe mosaic, C with a mild strain, and D healthy plants. All were set at the same time. The two rows on the left were healthy plants set later.

est power microscope. The infective principle is considered to be an organism because it multiplies very rapidly after being introduced into the plant, and in filtration tests it has been found to be made up of definite particles. These particles pass thru the pores of coarser filters but may be held back completely by finer ones.

The disease is spread very readily, especially by workers. After the fingers become contaminated by handling a diseased plant, rubbing a healthy plant sufficiently hard to break the hairs on the surface of the leaf will infect it. The disease, therefore, if present in a few plants in the field, will usually be spread to many others during topping and suckering, and perhaps also during worming, thus explaining why so much of the new

sucker growth is often diseased following topping. The time required for symptoms of the disease to appear varies from about 4 days in young, vigorous plants to an average of about 12 days in the case of older plants in the field.

IMPORTANCE OF THE DISEASE

The lack of interest which growers have taken in the mosaic disease as compared with some other diseases of tobacco, indicates that they do not consider it of very great importance except where a large number of plants are affected and the crop is very appreciably injured. It appears certain, however, that the importance of the disease has been very much underestimated. On an average, 3 percent of the plants in fields of Burley tobacco are affected with the disease when growth commences following setting,¹ but it is not uncommon to find fields in which 10, 20 or even 50 or 60 percent of the plants are affected at this time, and one field was observed in which 96 percent of the plants had mosaic soon after transplanting. Altho the *average* early infection of 3 percent may not seem important, yet those growers with crops extensively diseased year after year may sustain very large losses.

The injury caused by infections at topping and suckering time, has been considered negligible by the grower and by those studying the disease. But recent experiments, altho covering only a single season, suggest that late infections may be much more injurious than the early infection of an occasional plant. These tests showed that whereas infection at topping time appeared to have no visible effect on the plant, other than the production of mosaic in the suckers, yet when the diseased and healthy plants were cured and graded, the mosaic plants were reduced in quality about 25 percent as compared with the healthy plants.² Those inoculated at setting time were reduced in quality about 40 percent and when reduction in yield

¹ These figures are based on counts of about 134,000 plants in 33 fields of tobacco in Fayette County, following setting, in 1927.

² Valleau, W. D. and E. M. Johnson. The effect of a strain of tobacco mosaic on the yield and quality of Burley tobacco. *Phytopathology*, XVII, 523-527. 1927.

was included the loss was approximately 60 percent.³ Thus, in addition to the visible injury due to stunting, mottling and often burning of the leaves, which is obvious to the grower, there is an important invisible injury which becomes evident only by carefully conducted tests but which reduces the value of the cured crop strikingly.

DISTRIBUTION OF MOSAIC

Mosaic has been reported in all the tobacco growing regions of the world and is present to a greater or less extent in most of the tobacco fields of Kentucky each year, judging by observations made over a series of years in various parts of the State. It is evident, therefore, that the problem of the control of this disease is of importance to every tobacco grower, wherever located.

OVERWINTERING OF THE MOSAIC DISEASE

Very little has been known as to how the mosaic disease of tobacco comes thru the winter and how it is transmitted to the first tobacco plants in the plant bed or field. Many growers are familiar with the peculiar distribution of mosaic plants early in the season, many rows, perhaps, being free from the disease and then a row occurs in which every plant for a short distance is diseased; or, if a setter has been used, every second plant may be diseased. This condition may continue for a few rows and again the plants may be healthy (Figure 5). Investigators have traced the original infection to the plant bed and have assumed that an occasional plant in the bed is diseased and that the peculiar results following setting are due to occasionally pulling diseased plants and spreading the disease to healthy ones. This is undoubtedly the true explanation when mosaic plants are present in the bed, but extensive observations of plant beds in Kentucky before pulling time make it appear very improbable that infected plants in the bed at first pulling are of much consequence in the mosaic problem.

³The inoculations and other field operations were performed by the writers, care being used that the plants selected as healthy were free from mosaic at second suckering. The stripping and sorting were done by the farm hands and the grading by Head Grader, Mr. John Corlis, and Mr. Klein of the Burley Tobacco Growers' Cooperative Association. The basis for estimating value was the advance being paid on the grades of tobacco under consideration at that time.

Overwintering of tobacco mosaic in solanaceous weeds or weeds of the potato family was reported about 14 years ago.⁴ Recently these weeds have been shown to be important as overwintering agents of tomato mosaic,⁵ and their eradication in and about tomato fields resulted in greatly reducing the amount of mosaic which developed. The solanaceous weeds undoubtedly carry mosaic, as inoculations from horsenettle (*Solanum carolinense*) and groundcherries (*Physalis* sp.) to tobacco, have quite often produced mosaic.⁶

Altho these weeds carry the mosaic disease over winter, observations over a period of several years indicate quite clearly that on the Experiment Station farm, at least, where infected weeds are present in abundance, they are of little or no importance in causing mosaic in the bed. There is however a certain amount of field infection which takes place during the summer which may probably be traced to them. During the past six years the writers have made careful inspections of all the plant beds on the Experiment Station farm at setting time and have personally pulled thousands of plants for setting, but have not found a single mosaic plant in any of the beds at the time of first pulling. About two weeks later, or when the beds were pulled a second time, an occasional mosaic plant could be found each year during the first years of the work. During the past two years, however, no mosaic plants have been found at approximately three weeks after pulling, except where infected tobacco material was used purposely on the hands while pulling. Altho mosaic weeds were quite abundant near these beds each year, they appeared to play no part in the early spread of the disease, as will be pointed out later. There is also considerable evidence from the western part of the State which indicates that if certain simple precautions are taken in handling plants, little is to be feared from mosaic carried over winter in weeds.

⁴ Allard, H. A. The mosaic disease of tobacco. U. S. Dept. of Agr. Bul. 40:1-33. 1914.

⁵ Gardner, Max W. and James B. Hendrick. Overwintering of tomato mosaic. Bot. Gaz. 73:469-485. 1922.

Field control of tomato mosaic. Phytopathology XIII. No. 8, 372-375. 1923.

⁶ Valteau, W. D. B. P. I. Plant Disease Survey Bul. 6; No. 5, p. 96, 1922.

Overwintering of mosaic in cured tobacco has been recognized as a possibility for many years, but little practical application has been made of the fact that the virus does not die in cured tobacco over a period of a year or two. In 1914 Clinton⁷ warned the growers of Connecticut against the use of tobacco infusions or tobacco trash as fertilizer on tobacco beds since it would introduce the disease into the bed. This recommendation is as important now as it was then. Fortunately comparatively few Kentucky tobacco growers practice this method of plant bed fertilization, using the simpler and less dangerous practice of adding nitrogen in the form of sodium nitrate or ammonium sulfate.⁸

Because of the very common habit which our tobacco growers have of chewing natural leaf tobacco, the fact that the virus of mosaic lives over winter in cured tobacco assumes an importance in the mosaic problem which can hardly be overemphasized. A simple experiment carried on in 1926 at the Kentucky Experiment Station illustrates the importance which may be attached to cured tobacco in the overwintering of the disease and how readily the disease may be transmitted from cured tobacco to healthy plants.

Plants were pulled with clean hands from a bed where there was no evidence of mosaic and then an equal number of plants were pulled from the same bed, dipping the hands occasionally into water in which cured natural tobacco leaves had been soaked. The two lots of plants were then set in alternate rows on June 10, 1925. On June 29 records were made of the condition of the plants with the result shown in figure 4.

In this test the 138 plants pulled with clean hands were free from mosaic 19 days after setting while at the same time 70.9 per cent. of the plants pulled with hands dipped in the tobacco water had developed mosaic. Two months after, only 15 mosaic plants were present in check rows 1 and 3, illustrating how slowly the disease spreads in the field when the plants are not handled.

⁷ Clinton, G. P. Chlorosis of plants with special reference to calico of tobacco. Connecticut Agr. Exp. Sta. Ann. Report of 1914, Part 6, p. 357-424.

⁸ For more complete directions on the preparation and fertilization of tobacco beds, see Kinney, E. J., Management of tobacco plant beds. Univ. of Ky., Col. of Agr., Extension Div. Circ. 77. 1922.

This experiment demonstrates clearly that the disease is carried in cured tobacco and that it may be readily transmitted from it to healthy plants while pulling. The importance of the knowledge that mosaic overwinters in natural leaf tobacco lies in the fact that a large majority of tobacco growers in Kentucky chew natural leaf tobacco, nearly all of which carries the disease.

Row

1 .MMMMMM.MM.....M..MMM..M.
 2 ..MMM.M.M.MM.....MM.MMMMMM.....
 3
 4 ...M.....MM.MM.MMM..M..MMM.M.....M..
 5M...MM.MM.M...MM..MMM.M.M.M.MMM.....M
 6
 7

Figure 6. The effect on development of mosaic of chewing natural leaf tobacco and occasionally spitting on the fingers while pulling tobacco plants. Rows 3, 6 and 7 were pulled with clean hands. Plants set June 15, 1927; observations made July 6, 1927. M stands for mosaic plant, . for healthy plant.

Tobacco juice is wiped from the mouth with the hands and thus, while pulling plants, some of the infective material comes into contact with a healthy but slightly bruised plant and inoculation occurs. In the following pages evidence will be presented showing the importance of this source of infection and the possibilities of controlling mosaic by avoiding the use of infected tobacco while working in the plant bed.

MOSAIC CONTROL STUDIES ON THE EXPERIMENT STATION FARM, LEXINGTON

During the past six years observations and experiments have been made to determine the original source of mosaic in tobacco grown in a fixed rotation on the Experiment Station farm. For the first three years records were kept of the exact distribution of the disease in the field about three weeks after setting to see if this would throw any light on the original

source of the disease at pulling time. At the same time the beds were watched carefully to see to what extent the disease might be present in them and thus explain field infection. A typical example of the distribution of mosaic in this rotation, before efforts were made to control the disease, is shown in figure 5 in which the dots represent healthy plants and M represents mosaic plants. Spaces where plants were lacking are not shown in this diagram, which explains the apparent differences in the length of the rows. The plants for this planting were pulled from a bed from which perennial solanaceous weeds had been removed the previous year, only 23 shoots of horse-nettle being found in 540 square yards of bed in 1924. No mosaic plants were found in the bed at the time the plants were pulled. A study of figure 5, with these facts in mind, leaves little doubt that differences in amount of infection in the field trace back to the plant pullers. In rows 35, 37 and 38 are instances in which every second plant is infected for some distance in the rows. The plants were set by machine so that the infected plants came from the plants handled by one man and the healthy plants from those handled by the other man on the setter. The fact that six rows are nearly free from mosaic plants suggests that another man pulled these 600 plants. Altho no record was kept we know positively that some of the men who pulled plants for this field chewed natural leaf tobacco while pulling.

In 1925 the plants for this field were pulled by two men who chewed commercial plug and one who did not chew at all until toward the end of the planting when he chewed natural leaf tobacco five years old. The percent of mosaic dropped from 8.7 in 1924 to 2 percent in 1925. In 1926 and 1927 sterile chewing tobacco was furnished the pullers and setters and in 1927 the added precaution was taken of having the men brush all old tobacco trash out of their pockets and wash their hands in soap and water before beginning to pull. The results obtained over the six years in which records were kept of mosaic in this field are given in Table 1. They show that where natural leaf tobacco was chewed while pulling plants mosaic infection was high, whereas when sterile tobacco was substituted, the

disease was practically eliminated as far as early infection at setting time was concerned. The results are based on about 13,000 plants set each year.*

TABLE 1.—The Effect of Chewing Natural Leaf Tobacco While Pulling Tobacco Plants on the Percent of Mosaic Following Setting.

Year	Kind of Tobacco Chewed	Percent of Mosaic
1922	Natural leaf	9.0
1923	Natural leaf	6.0
1924	Natural leaf	8.7
1925	Commercial plug and natural leaf.....	2.1
1926	Sterile leaf and plug.....	0.44
1927	Sterile leaf and plug.....	0.05

Altho exact records have not been kept during the entire period on other fields of tobacco on the Experiment Station farm, enough records are available to show clearly that the same condition existed in other fields previous to adopting the use of sterile chewing tobacco as in the field referred to in table 1. In 1927, in a total of about 70,000 plants set on the farm, where precautions were taken to prevent mosaic infection, but 1 mosaic plant was found in every 2,222 plants, about three weeks after setting as compared with 1 in 12 to 16 in years when natural leaf tobacco was chewed while plants were being pulled.

Chewing tests in which natural leaf tobacco was chewed while plants were being pulled, show clearly that the amount of infection observed in the rotation field and in the other fields on the farm during the years when natural leaf tobacco was used, can be accounted for from this source. In 1927 one of the plant pullers was given natural leaf tobacco known to carry the disease and was asked to chew it while pulling plants and to spit on his fingers occasionally. Other plants were pulled by the writers after washing the hands in soap and water and both lots were set in the same plot after again washing the hands, thus largely

*Since this bulletin has gone to press, the results on this and other fields for 1928 have been obtained. Plants for these were pulled from an apparently mosaic-free bed by two men, one of whom chews natural leaf tobacco and the other does not use tobacco. Sterile tobacco was given to the man who chewed when he came to work in the morning. He washed his hands in water without soap, and started pulling plants. The first five rows set, totaling 586 plants, averaged 5.5 percent mosaic, while the remainder of the field totaling 14,541 plants averaged .06 percent. During the next several days, during which only sterile chewing tobacco was used, 39,780 more plants were pulled by these two men, of which only 9 developed mosaic, or an average of .02 percent. These results emphasize the necessity of thoroughly scrubbing the hands in soap and water if a person who chews natural leaf tobacco is to pull plants.

eliminating any chance of infection while setting. The amount of mosaic 2 days after setting is shown in figure 6. Forty-four percent of the plants pulled with contaminated fingers had developed mosaic. At that time there was some question as to the condition of certain plants, as growth had been slow, therefore counts were made again 47 days after setting, when 108 plants of rows 1, 2, 4 and 5 had mosaic and 26 were healthy, while in check rows 3, 6 and 7 a total of 76 plants were healthy and none had mosaic. Thus, as a result of chewing natural leaf tobacco and spitting on the fingers while pulling plants, 80 percent of the plants became diseased, while in the check rows, even tho a period of 47 days had elapsed since setting, none of the plants were affected. Ninety-eight days after setting a total of 10 plants in the check rows had developd the disease, showing again the extremely slow rate of natural spread. At that time the plants had not been handled unless it occurred during cultivation.

Pulling plants while chewing natural leaf tobacco but making no special effort to contaminate the fingers will, of course, result in less infection than if the fingers are intentionally contaminated at frequent intervals while pulling. This is brought out in the following tests, in one of which the man who pulled plants for the experiment reported in figure 6 again pulled while chewing tobacco known to carry the disease. In this test he was asked not to make any special effort to contaminate his fingers, only wiping his mouth occasionally. He pulled a total of 878 plants of which 39, or 4.4 percent developd mosaic; while 837 plants pulled with clean hands and set in alternate rows developed but one case of the disease in 48 days. Another man who had pulled for the general plantings in 1927, pulled 360 plants for a small plot; of these 19, or 5.2 percent developd mosaic. In these two small plantings totaling 1238 plants, nearly twice as many mosaic plants occurred as in the remaining plantings on the Experiment Station farm with a total of nearly 55 times as many plants.

MOSAIC CONTROL ON THE EXPERIMENT FARM AT PRINCETON

Tobacco has been grown two years on the Sub-Experiment Station farm at Princeton. Both years efforts were made to control mosaic by not allowing the men pulling and setting plants to chew any tobacco during these operations. The results are given in table 7 and show that practically complete control was obtained both years. Observations each year were made after the plants had attained considerable size so that any infection occurring at setting time should have been apparent.

TABLE 7.—Mosaic in General Plantings at Princeton. No Tobacco was Used While Pulling and Setting.

Year	No. of Plants Examined	Percent Mosaic
1926	8,500+	0.00
1927	11,700	0.08

Chewing tests were conducted both years. In 1926, 614 plants were set in three plots of 3 rows each with 3 check plots of equal size alternating. The plants were pulled and set June 1 while the men were chewing their own natural leaf tobacco. The plants for the check plots were pulled and set after the men had washed their hands in soap and water. A record of the results was not made until 49 days after setting, at which time the plants were more than knee high and showed considerable evidence of spread of mosaic as far away as 47 rows. In the rows set with plants pulled while the men were chewing tobacco, many mosaic plants were evidently the result of early infections, while a few others, including the mosaic plants which appeared in the check rows, appeared to be more recently infected, as only the growing points were mottled. Spread may have been due to worming or to hoeing and weeding about the plants or possibly to insects. The counts obtained 49 days after setting are given in table 8 and show that about 1/3 of the plants pulled and set while the men were chewing natural leaf tobacco develop the disease while but 1/10 of those pulled and set with clean hands had develop it at that time. Counts were made in other parts of this field to see to what extent mosaic had spread. Groups of

rows 5 to 8 and 19 to 22 in the plot next to the mosaic test each had a total of 5 mosaic plants, while rows 33 to 36 had 4 mosaic plants, making slightly more than one mosaic plant to each row observed. The results leave little doubt that most of the infection in the rows pulled and set by men chewing natural leaf tobacco was due to infection transferred from the chewing tobacco to the plants while pulling or setting. The mouth was wiped at frequent intervals by the men while chewing and pulling plants at the same time.

TABLE 8.—Infection of Tobacco Plants from Natural Leaf Chewing Tobacco. Number of Mosaic Plants in the Field 48 Days After Setting.

Row No.	Pulled and Set While Chewing		Row No.	Pulled and Set With Clean Hands	
	Mosaic	Healthy		Mosaic	Healthy
1—3	88	128	4—6	18	198
7—9	88	128	10—12	27	189
13—15	43	173	16—18	13	203
Totals	219	429		58	590
Percent Mosaic	33.8			9.0	

In 1927 a similar test was conducted, but tobacco was chewed which was selected at random from the 1926 crop. With the exception of the chewing test plot, tobacco raised at Princeton in 1926 was practically free from mosaic. The results obtained are of interest in view of those obtained the previous year at Princeton and at Lexington where the chewing tobacco came either from plants known to be diseased or from fields in which mosaic was likely to have been abundant. The results obtained are as follows:

Rows 1, 2, 3, 7, 8, 9 plants pulled with clean hands, 712 plants, 1 mosaic.

Rows 4, 5, 6, 10, 11, 12 plants pulled while chewing 1926 tobacco, 712 plants, 4 mosaic. As some effort was made to contaminate the fingers while pulling plants, it seems evident that mosaic-free tobacco was used in this test.

MOSAIC CONTROL ON SOIL EXPERIMENT FIELDS

Tobacco is grown on four of the soil experiment fields of the Kentucky Experiment Station. These are located at Greenville, Mayfield, Hopkinsville and Campbellsville. As they are cared for by farmers, the results obtained on them should be indicative of what might be expected on the average farm. Since 1925, the caretakers have been warned not to use any tobacco while working around the plant beds or setting plants, but at Mayfield in 1927 a new man overlooked the instructions and employed two workers who chewed natural leaf. Records have been made each year, more than a month after setting, of the number of mosaic plants present at that time. The results obtained are given in table 9. The summary of the counts from the nine crops on which results were obtained show that in 8 of them natural leaf tobacco was not used by the men handling the crops and but 13 mosaic plants were found in a total of more than 33,671 plants set or .04 percent, all of which were on the same field in two successive years. At Mayfield, in 1927, where natural leaf tobacco was used by two men pulling plants, 41 percent of the plants had developed mosaic by August 26, and most of these appeared to be early infections.* The final observations on the 1927 crops at Greenville and Campbellsville were taken after topping and first suckering, when both crops were found to be free from mosaic, indicating that it is possible to bring tobacco thru the summer free from this disease if proper precautions are taken.

*Mosaic spread by a smoker who rarely uses chewing tobacco was demonstrated at Mayfield in 1928. This man, who did all the work, carries cured tobacco loose in his pocket and, before filling his pipe, crushes the tobacco in one hand with the side of the other. Thus his hands must become thoroly contaminated. He pulled and set two lots of plants, alternating pairs of rows. The first pulling had approximately three times as many mosaic plants as the second. The field averaged 6 percent mosaic.

TABLE 9.—Mosaic in Plantings of Tobacco on Soil Experiment Fields

Location	Date Observed	No. Plants	Set by	Results
Greenville	7/13/25	6000+	6 men, no tobacco used	No mosaic
	7/21/26	4080	4 men, no tobacco used	No mosaic
	8/24/27	4080	4 men, no tobacco used	No mosaic*
Mayfield	7/13/25	2520	1 man, no tobacco used	No mosaic
	7/19/26	2520	1 man, chewed "Apple Suncured Plug"	No mosaic
	8/26/27	2520	3 men, two chewed natural leaf while pulling plants	41% mosaic
Hopkinsville ..	7/14/25	3584	3 men, 1 chewed plug..	7 mosaic plants
	7/20/26	5887	No tobacco used.....	6 mosaic plants
Campbellsville	9/16/27	5000	No tobacco used.....	No mosaic*
Total		36191		

Summary—

No natural leaf tobacco chewed, 33,671 plants; .04% mosaic
 Natural leaf tobacco chewed, 2,520 plants; 41.0 % mosaic

Total plants observed 36,191 plants

*Inspections made after topping and first suckering.

Solanaceous weeds (horsenettle and groundcherries) were present in the alleyways in each of these fields but appeared to play no part in mosaic spread, with the possible exception of the Hopkinsville field where both years mosaic plants were found in nearly the same location. Mosaic is common in tobacco in the vicinity of these fields so that the results appear to be of considerable significance in the mosaic control problem.

THE RELATION BETWEEN CHEWING TOBACCO AND MOSAIC IN COMMERCIAL PLANTINGS

During the summer of 1927, thirty-three fields of tobacco were observed in Fayette County with the object of determining to what extent the results obtained experimentally in the control of mosaic would apply on the average farm. The counts were obtained about a month to six weeks after setting and for the most part represent infection which occurred at setting time. After a number of fields had been inspected it was found not at all difficult to predict the habits of the man or men who pulled the plants with respect to the use of chewing tobacco. Where a large amount of mosaic was found, the plants were invariably

pulled by men who chewed natural leaf tobacco, whereas where only an occasional diseased plant was found, either the men who pulled did not use tobacco at all or were very clean in their habits. In one case a man chewed natural leaf tobacco but took only 2 chews a day; one when starting work in the morning and the other after lunch at noon. It is obvious that but very little mosaic could result from such a habit. A summary of the data obtained in this survey is given in table 10.

TABLE 10.—Mosaic in Commercial Plantings of Tobacco and the Habits of the Grower with Respect to the Use of Tobacco.

Habits of Pullers	No. of Fields	No. Plants Observed	No. Mosaic Plants	Percent	
				Average	Range
Chewed natural leaf tobacco not cleanly	26	100,993	3,135	3.1	.9 to 21.5
Chewed natural leaf tobacco, but cleanly	2	12,515	80	.64	.2 to 1
Did not use tobacco	5	20,963	118	.56	.03 to 1.3

The results, altho not so striking as those obtained under better controlled conditions, are in line with the experimental results. It was not always easy for a grower to remember everyone who had pulled plants, and his habits with respect to chewing tobacco, so that it is probable that when tests are carried on with farmers who are warned in advance of the importance of chewing tobacco, more complete control may be obtained. However, with only 1 mosaic plant in 200, as where no tobacco was used, or where men chewed but were careful not to contaminate their hands, control may be considered to be satisfactory, as the few mosaic plants which develop may be hoed out at the first cultivation with no appreciable loss.

Mosaic in dark tobacco appears to be spread in the same way as in Burley but such accurate records have not been obtained in the dark tobacco area as in the Burley section. The observations in dark tobacco fields are of considerable interest, however, as they show something of the distribution of mosaic in the dark tobacco area and confirm the conclusion reached in experimental

studies as to the importance of natural leaf chewing-tobacco as a source of infection. In table 11 are recorded observations made in dark tobacco fields in 1927.

TABLE 11.—Mosaic in Tobacco Fields in Western Kentucky, August 24 to 27, 1927.

County	Mosaic Present	Habits of Growers
Muhlenberg	2 plants	Chews Fishhook plug (mosaic free)
McCracken	None seen	?
McCracken	Considerable	Chews natural leaf
Graves	Slight	?
Graves	Considerable	?
Graves	Considerable	?
Christian	Considerable	?
Christian	About 50%	?
Christian	Early setting } slight	Chews natural leaf
	Late setting } abund't	
Christian	Considerable	Chews natural leaf
Christian	Considerable	Chews natural leaf
Christian	Considerable	Chews natural leaf
Christian	Slight	?
Christian	Considerable	Chews natural leaf
Christian	Slight	?
Webster	6 fields, no mosaic	Pullers did not use tobacco
Webster	No mosaic	Chews natural leaf, but never when working in plant bed
Webster	In one corner of field	Did not use tobacco, but corner of field inspected by neighbors who chewed natural leaf
Webster	No mosaic	1 of 5 men who pulled chewed natural leaf, but he was cleanly in habits
Webster	Considerable	Chews natural leaf
Webster	Considerable	Chews natural leaf
Summary	Mosaic present 17 fields	Natural leaf tobacco used 8
		Habits not known 7
		Chewed commercial tobacco 1
		No natural leaf tobacco used 1
	No mosaic present, 9 fields	No natural tobacco used 7
		Natural leaf tobacco used 1
		Habits not known 1

The data, altho not complete, indicate that wherever natural leaf tobacco was known to have been used, mosaic was present rather abundantly, whereas in 7 fields where no tobacco was used, no mosaic could be found.

The observations made in Webster County are worthy of further comment. As will be seen in table 11, a considerable number of fields appeared free from mosaic. This is quite unusual as no other neighborhood had been visited where mosaic was not present in nearly every field. After several fields had been inspected, County Agent Dickey suggested as the reason that many tobacco growers in that vicinity belong to a religious sect which prohibits the personal use of tobacco in any form altho they were allowed to raise it. Two fields in the same area set with plants pulled by men who chewed natural leaf tobacco showed quite extensive infection.

MOSAIC AND COMMERCIAL TOBACCO

As natural leaf tobacco practically always carries mosaic, its use should be eliminated entirely by the tobacco grower during the plant bed season. The results on the Experiment Station farm show that the use of sterile tobacco is as safe as if no tobacco were used. Is there, then, a source of chewing tobacco which is free from mosaic?

Tests of 45 commercial brands of tobacco have been made to determine whether they carried mosaic.⁹ The results of these tests showed that in general cigarettes and granulated smoking tobaccos may be expected to carry the virus. Four commonly used brands of plug chewing-tobacco seemed to carry the disease rather consistently, making their use questionable, while the commercial *scrap and twists so far as investigated seemed to be entirely free* from the virus which causes the disease, and to be safe to chew while pulling plants.

Old natural leaf tobacco seems to carry the virus in as virulent a form as fresh tobacco, and therefore should not be used with the mistaken idea that age kills the virus. The disease has been produced by inoculations with samples of tobacco 5, 16, 17, 18, 20, 30 and 31 years old.⁹

⁹ Valleau, W. D. and E. M. Johnson. Commercial tobaccos and cured leaf as a source of mosaic disease in tobacco. *Phytopathology* XVII, 513-522. 1927.

THE RELATION OF WEED HOSTS TO SPREAD OF MOSAIC IN THE FIELD

The fact has been mentioned that certain weeds, particularly horsenettle and groundcherries, may carry mosaic over winter and that in the case of tomato mosaic they appear to be of importance as sources of infection. The work reported in this bulletin indicates that these weeds are of comparatively little importance in tobacco fields in western Kentucky, as the mosaic-free fields in Webster County had all been topped when the observations were made, and on at least two of the soil experiment fields crops were brought thru to second suckering with no mosaic. These weeds are not as abundant in western Kentucky as in the more fertile soils of the Bluegrass section of the State.

In the Bluegrass section weed hosts are often abundant, especially in old bluegrass pastures. If tobacco is grown from time to time in such fields the weeds become infected and seem to carry the disease for years. Certain other virus diseases of tobacco¹⁰ appear to be carried in the same weeds and perhaps in other common ones also, which rather complicates the problem of control of the virus diseases in an occasional field. In our observations the weeds have appeared to be of importance in connection with the true mosaic disease in only two or three of the cases observed, and the distribution of the other virus diseases is not yet so extensive as to concern many tobacco growers. In only a few cases may it be necessary, if the elimination of chewing tobacco fails to give control, to resort to the elimination of the weed hosts in order to obtain control of true mosaic¹¹ if we may judge by past experiences.

Perhaps as serious a weed problem occurs on the Experiment Station farm at Lexington as can be found in the Burley section. Tobacco is grown in comparatively small plots surrounded by grass roadways and the weeds become quite abun-

¹⁰ Valteau, W. D. and E. M. Johnson. Some virus diseases of tobacco in Kentucky. Abs. in *Phytopathology*, Jan., 1928.

¹¹ The term "true mosaic" is used here to designate the group of similar virus diseases of tobacco which are commonly referred to in the literature as typical tobacco mosaic and which are characterized by the ability of the virus to remain virulent in tobacco after it is cured. This character seems to distinguish the true mosaic disease from the other virus diseases of tobacco commonly found in Kentucky.

dant in these roadways and often are diseased. At least 7 distinct virus diseases develop in tobacco growing in these plots, and all but the true tobacco mosaic appear to originate only from wild host plants, as there is no evidence that any of them live thru the winter in cured tobacco, and inoculation tests with dried tobacco have given negative results.

Under these conditions there is a slow but steady spread of true tobacco mosaic thruout the summer. In 1927 counts were made from time to time during the summer in all plantings on the Experiment Station farm to determine the rate of mosaic spread. A summary of the results of counts on 67,983 plants, made at four periods during the summer is given in table 12.

TABLE 12.—Spread of Mosaic, on the Experiment Station Farm, Which Might be Attributed to Weed Hosts.

	Plants Topped			
Days after setting	22-29	41-48	62-65	76-104
Mosaic plants	26	164	385	2410
Percent04	.24	.57	3.55

The results indicate that altho there is a spread of tobacco mosaic, apparently from weed hosts during the summer, it is insignificant, amounting to only .57 percent before topping. The spread during topping was considerable, being 3.55 percent, but no efforts were made to prevent spread from diseased plants to healthy ones while topping. It is probable that the destruction of the few mosaic plants which develop during the summer would have completely eliminated spread during topping and suckering. It so happens that because of the serious problem presented by certain weeds as hosts for other virus diseases on the Experiment Station farm their destruction will be necessary, but it is not anticipated that weed destruction will usually enter into the tobacco mosaic control problem in Kentucky except in isolated cases. In table 13 are given figures showing the prevalence and spread of mosaic and the other virus diseases of tobacco on the Experiment Station farm in 1927 and their prevalence in farms scattered over Fayette County. The virus diseases other than mosaic and ring-spot have not yet been accurately described in publications, but it is hoped that this may be done in the near future.

**THE RELATION OF INFECTIOUS CHEWING TOBACCO TO THE
TOMATO MOSAIC PROBLEM**

It has been demonstrated in Kentucky and elsewhere that the true mosaic disease of tobacco is identical with one of the common mosaic diseases of tomatoes, altho there are at least 6 other distinct viruses which may cause tomato mosaic in Kentucky. Our experiments in using natural leaf chewing tobacco while handling tomato plants have demonstrated clearly that the disease is spread as easily to tomatoes by this means as it is to tobacco, consequently tomato growers should be careful never to chew natural leaf tobacco while handling tomato plants. It may be necessary to go so far as to warn against the use of cigarettes by men working in commercial greenhouses where tomatoes are grown, as a single plant infected during a season by this means may be sufficient to spread the disease to all of the plants in the house.

TABLE 13.—The prevalence of seven virus diseases of tobacco on the Experiment Station farm at Lexington and on farms well distributed over Fayette County. The figures for the Experiment Station fields indicate the spread of the virus diseases during the summer. Apparent decreases in ring spot and other virus diseases after the middle of summer are due to difficulty in recognizing plants with only an occasional ring or mild symptoms.

Experiment Station Fields	Date Observed	Percent						No. of Plants Observed	Remarks
		Mosaic	Coarse Etch	Ring Spot	Etch +	Etch	Vein Border	Puff	
Bl. 15, Ser. 1 Pl. 10-16	7/5/27	0.03		0.07					
	7/27/27	.4		3.2		0.5	0.5		
	8/13/27	.5	0.5	5.2	0.07	.4	.9	0.5	
	8/29/27	.5	.8	4.5	.03	.4	1.4	.3	Nearly all plants topped. Mosaic plants not handled.
	9/22/27	11.4		2.3	.05	3.3	4.6	.3	Topped and suckered. Mosaic plants handled.
Bl. 15 & 20, Ser. 4, Pl. 1-16	7/8/27			.3					
	7/27/27	.04	.1	1.0		.07	.1	.1	
	8/24/27	.4	.2	2.0	.1	.07	.3	.3	
Bl. 7, Ser. 2	7/1/27	.04	.01	.04					
	7/20/27	.4	.1	.6	.07	.2	.03	.3	Counts in second suckers, no attempt made to prevent spread of mosaic following setting.
	8/11/27	1.2	.2	1.7	.2	.5	.5	.7	
	9/10/27	8.3	.3	3.7	.0	6.2	7.1	2.7	
	9/10/27	8.6	.1	1.6	.2	3.0	2.4	.3	
	9/10/27	10.7		1.3	.1	1.7	.8	.7	
Bl. 11-12	7/5/27	.05		.05		.01			
	7/25/27	.2		1.0	.01	.4	.2	.2	
	8/12/27	.6	.1	1.8	.1	.3	.4	.5	
Woodland Ave. field	9/1/27	2.2	.1	1.6	.1	.1	.8	.4	100 rows.
									100 rows. Plants topped.
	7/22/27	2.2		8.0		.8	6.1	.8	Plants topped. Solanaceous weeds very abundant. Puller chewed natural leaf tobacco.

Fields in County	Date Observed	Percent						No. of Plants Observed	Remarks
		Mosaic	Coarse Etch	Ring Spot	Etch +	Etch	Vein Border	Puff	
1	7/29/27	1.0		.4		.1	1.1		Near a potato field being dug. Pullers did not use tobacco. First in- spection.
2	7/12/27	.03							
2	7/29/27	.1		.2		.4	2.8	.2	Near potato field recently dug. Second inspection.
3	7/29/27	4.7		.1		.6	.2		Near small plot of potatoes. Pullers chewed natural leaf.
4	7/12/27	5.0							Pullers chewed nat. leaf, planting about 100 acres and nearly free from weeds.
5	7/12/27	11.6		.05		.03			
6	7/14/27	.9		.6		1.3			Mottled solanaceous weeds abundant. Pullers did not use tobacco.
6a	7/14/27	1.3		.06					Evidence of mosaic spread at pulling. Horsenettles fairly abundant. Puller did not use tobacco.
7	7/14/27	10.4		.08		.04			Mosaic infection evidently at pulling.
8	7/14/27	7.4		.7		1.0			Many mosaic tobacco plants in bed. Puller chewed natural leaf.
9	7/19/27	4.6		.06		.5			Pullers chewed natural leaf.
9a	7/19/27	3.3				.8			Pullers chewed natural leaf.
10	7/19/27	21.5							255 Pullers chewed natural leaf. Not cleanly.
11	7/19/27	.4		.09		2.8			One man does own work and does not use tobacco.
12	7/19/27	2.4							Hires miscellaneous help; about 10 acres or more in field.
13	7/19/27	.2		.3		1.9			No tobacco used by family who do all work.

Fields in County	Date Observed	Percent						No. of Plants Observed	Remarks
		Mosaic	Coarse Etch	Ring Spot	Etch +	Etch	Vein Border	Puff	
14	7/18/27	.9		.3				7,620	Pullers chewed natural leaf.
15	7/18/27	1.8		.9				4,244	Pullers chewed natural leaf. Not cleanly.
16	7/18/27	6.7		.5				1,842	
17	7/18/27	3.8		.3				1,416	
18	7/18/27	.9		.1				2,976	
18a	7/18/27	1.2						2,169	
19	7/18/27	4.9						1,140	Pullers chewed nat. leaf. Not cleanly.
20	7/18/27	.2		0.1				4,332	Thought some men chewed while pulling.
20a	7/18/27	2.5		.04				2,618	Thought some men chewed while pulling.
20b	7/18/27	.5		.1				2,703	Thought some men chewed while pulling.
21	7/18/27	.1		.3				1,800	Thought some men chewed while pulling.
22	7/18/27	.9		2.7				1,620	Chewed natural leaf.
23	7/16/27	.4		.1				4,819	One man chewed nat. leaf while pulling 1 tub of plants; area set with these plants readily found.
24	7/16/27	.02		.05				5,827	Many solanaceous weeds but none ap- peared diseased.
25	7/16/27	.6		.5				1,483	First setting. Pullers chewed plug and natural leaf.
25a	7/16/27	5.8		.7		.06		1,637	Second setting from same bed.
26	7/16/27	.9		5.7				7,000	2 men chewed nat. leaf but very cleanly in habits.
27	7/16/27	4.1						5,021	Pullers chewed natural leaf.
28	7/14/27	10.8		.1		.2		1,854	Chewed natural leaf; not cleanly.
29	7/14/27	4.3		.2		.8		2,646	Pullers chewed natural leaf.
30	7/14/27	.2		.3				4,530	2 men chewed natural leaf but very careful in habits and used tobacco from relatively free crop.
30a	7/14/27	1.0						985	

RECOMMENDATIONS FOR THE CONTROL OF TOBACCO MOSAIC

In the preparation of the tobacco bed, burning or steaming should be done thoroly in order to reduce the necessary weeding to a minimum. The less work done about the bed, the smaller the chance of infection from chewing-tobacco or from mosaic carried in by insects while the tobacco cotton is removed.

No tobacco trash of any kind should be used on the bed, either for burning or for fertilizing, as stalks and pieces of leaf left about the bed may cause infection.

While weeding, pulling or setting plants the workmen should not use natural leaf chewing-tobacco nor allow anyone else who is using it to handle the plants. If it is necessary to chew during these operations, commercial twists may be used, but first all old tobacco trash should be cleaned out of the pockets. Workers who chew natural leaf tobacco should wash their hands in soap and water before beginning to pull plants, even if no tobacco is chewed while pulling, as the virus may remain on the fingers for some time and gradually come off on the plants as they are pulled.

If only an occasional plant develops the disease in the field, it is probably much safer to remove these as soon as found rather than leave them as centers for further insect spread and as sources of spread while topping and suckering.

Altho the evidence does not warrant a program of general destruction of horsenettles and groundcherries, it appears advisable where they are abundant to use a form of cultivator equipped with sweeps or knives which will cut the weeds off below the surface of the ground. A little more attention to their destruction than is now generally given, might ward off trouble in the future.

If the elimination of chewing tobacco fails to give control, it is probable that virus diseases other than the true mosaic are concerned, and attention to the eradication of possible weed hosts may be necessary to prevent loss in the future.

While hoeing, worming, topping and suckering, mosaic plants should not be touched with the hands, as the disease probably will be spread to many of the healthy plants handled later.

Either cut the diseased plants out as soon as found, or leave them strictly alone until they can be handled by themselves.

Of these recommendations the most important are those referring to the use of natural leaf chewing tobacco, and to the destruction or avoidance of mosaic plants in the field.

SUMMARY

1. The elimination of the mosaic disease appears to be an important factor in improving quality of tobacco. Early infections reduce yield and quality while late infections appear to injure quality.
2. Mosaic plants are rarely found in plant beds at the time of first pulling, where no natural leaf tobacco has been chewed by the workers while weeding the bed. In spite of this, high percentages of mosaic are often found in the field when growth commences following setting.
3. The mosaic disease overwinters in horesnetties and ground-cherries but these appear to be relatively unimportant as a source of infection at setting time. It also overwinters in cured tobacco and if this is chewed by men pulling plants and the mouth is wiped so that the juice gets on the hands, the disease may readily be transmitted to plants as they are pulled. This appears to be the chief early source of mosaic infection in Kentucky.
4. Commercial twists and scrap may be substituted for natural leaf chewing tobacco without danger of their transmitting the mosaic disease. Plug tobacco sometimes carries the disease but is preferable to natural leaf tobacco if tobacco must be chewed while handling plants.
5. The mosaic disease of tobacco has been completely controlled or reduced to a point where it is of little importance by the simple expedient of substituting sterile tobacco for the natural leaf tobacco usually chewed by the pullers or by prohibiting the use of tobacco completely by those working in the plant bed.
6. A survey study of mosaic in fields of Burley indicates that where natural leaf tobacco is chewed while plants are being pulled, relatively high percentages of mosaic follow, especially if the puller is not cleanly in his chewing habits, whereas fields set from plants pulled by persons who did not chew were relatively free from mosaic. The same results were observed in fields of dark tobacco in western Kentucky.
7. In western Kentucky and in most parts of the Burley section weed hosts of mosaic do not appear to be an important source of the disease in the field altho an occasional field may be found where, because of the presence of certain other virus diseases of tobacco in the weeds, their elimination may be necessary.
8. While it is not recommended that extensive efforts be made to destroy solanaceous weeds, yet where they are abundant it would probably pay in the future to give more attention than is generally given to their destruction.

9. Tomato mosaic may be caused by the tobacco mosaic virus and the disease may be transmitted as readily to tomatoes as to tobacco if diseased tobacco is being chewed by persons handling tomato plants.
10. Recommendations for the control of tobacco mosaic include thorough burning or steaming of the bed, keeping tobacco trash from the bed, elimination of natural leaf chewing tobacco while handling plants, the destruction of any mosaic plants which develop in the field or, if this is not done, making it a point never to handle a mosaic plant if healthy ones are to be handled subsequently.